

**METHODS OF SAMPLING AND TESTING**  
**MT-222-04**  
**METHOD OF TEST FOR DETERMINING THE**  
**IN-PLACE MOISTURE AND DENSITY OF SOILS**  
**BY THE SAND CONE METHOD**  
*(Modified AASHTO T191)*

**1 Scope:**



This method of test is intended for determining the in-place density of soils. The apparatus described herein is restricted to tests in soils containing particles not larger than 50 mm (2 in.) in diameter.

- 1.2** The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right hand-place of figures used in expressing the limiting value, in accordance with AASHTO R 11.

**2 Referenced Documents:**

***AASHTO Standards:***

R 11 Indicating Which Place of Figures are to be Considered Significant in Specified Limiting Values.

***MT Materials Manual:***

MT 203 Unit Weight of Aggregate

MT 210 Moisture-Density Relations of Soils Using a 5.5 LB. Rammer and 12 Inch Drop

MT 215 Moisture content by Calcium Carbide Method

MT 227 Laboratory Determination of Moisture Content of Soils

**3 Apparatus:**

- 3.1** *Density Apparatus with Base Plate*--The density apparatus shall consist of a 4 liter (1 gal.) jar and a detachable appliance consisting of a cylindrical valve with an orifice 12.7 mm (2 in.) in diameter and having a small funnel continuing to a standard G mason jar top on one end and a large funnel on the other end. The valve shall have stops to prevent rotating the valve past the completely open or completely closed positions. The apparatus shall conform to the requirements shown in Figure 1. The apparatus described here represents a design that has proven satisfactory. Other apparatus of similar proportions will perform equally well so long as the basic principles of the sand-volume determination are observed. The base plate is required for calibrations and testing.

- 3.2** *Calibration Container*—A sturdy cylindrical container of known volume ( $V_c$ ). The container shall be dimensionally approximate the largest test hole that will be dug. The container shall be calibrated according to MT 203.

*Note 1 – The internal diameter of the container shall be equal to or slightly less than the diameter of the opening of the base plate used with the sand cone.*

- 3.3** *Sand*--Any clean, dry, free-flowing, uncemented sand having few, if any, particles passing the 0.075 mm or retained on the 2.00 mm sieves. In selecting a sand for use, several bulk density determinations should be made using the same representative sample for each determination. To be acceptable the sand shall not have a variation in bulk density greater than 1 percent.

- 3.4** *Balances*--A balance or scale of 10 kg. capacity accurate to 1.0 g. and a balance of 500 g. capacity accurate to 0.1 g.

3     **Apparatus:** (continued)

3.5     *Drying Equipment*--Stove or oven or other suitable equipment for drying moisture content samples.

3.6     *Miscellaneous Equipment*--Small pick, chisels, or spoons for digging test hole; 254 mm (10 in.) frying pan or any suitable container for drying moisture samples; buckets with lids, seamless tin cans with lids, canvas sacks or other suitable containers for retaining the density sample, moisture sample or density sand respectively; thermometer for determining the temperature of water; small paint-type brush, slide rule, notebook, etc.

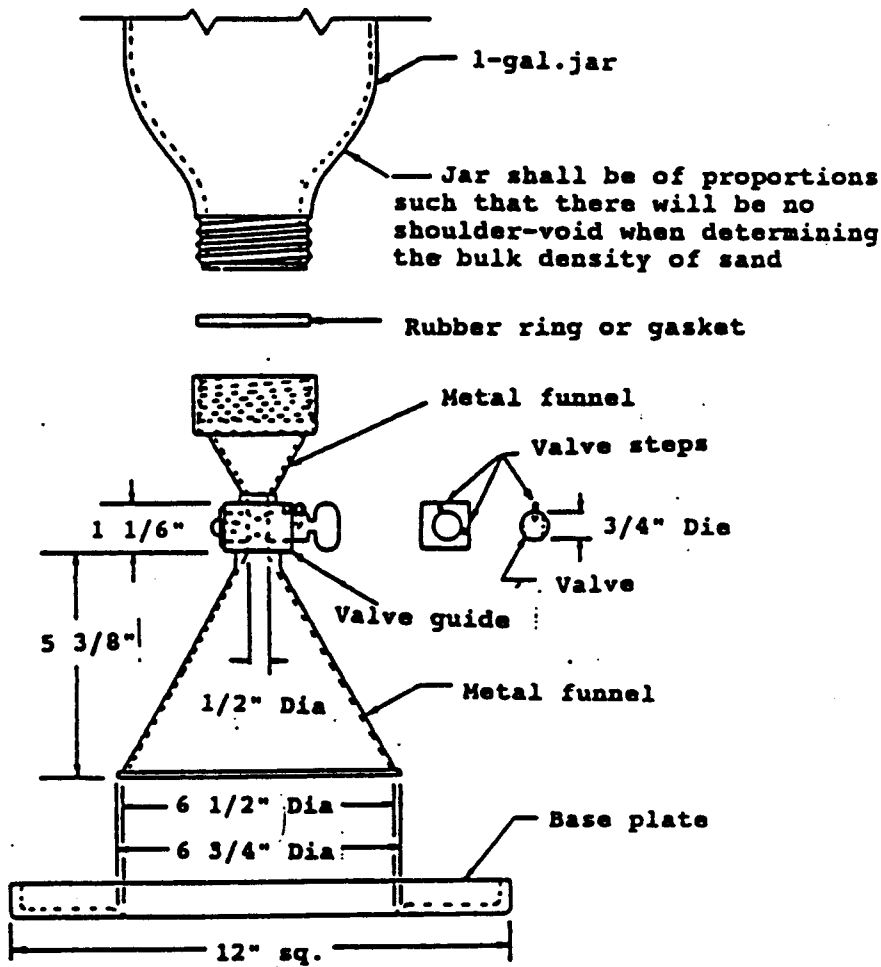


FIGURE 1 Density Apparatus

Metric Equivalents			
In.	mm	in.	mm
1/2	12.7	6 1/2	165.1
3/4	19.1	6 3/4	171.5
1 1/8	28.6	12	304.8
5 3/8	136.5		

#### 4 Cone Correction and Bulk Density Factors:

##### 4.1 Filling the apparatus:

- 4.1.1 Place the empty apparatus upright on a firm level surface, close the valve and fill the funnel with sand.
- 4.1.2 Open the valve and keep the funnel at least half full with sand during filling. When the sand stops flowing into the apparatus, close the valve sharply and empty the excess sand (Note 2).

*Note 2 – Vibration of the sand during any mass-volume determination may increase the bulk density of the sand and decrease the accuracy of the determination. Appreciable time intervals between the bulk density determination of the sand and its use in the field may result in change in the bulk density caused by a change in the moisture content or effective gradation.*

- 4.1.3 Determine and record the mass of the apparatus filled with sand ( $m_1$ ).
- 4.2 Determine the mass of sand required to fill the funnel and base plate (Cone Correction,  $C_c$ ).
- 4.2.1 Place the base plate on a clean, level, plane surface. Invert the sand-cone filled with sand and seat the funnel in the recess of the base plate.
- 4.2.2 Open the valve fully, and allow the sand to flow until the sand stops flowing (Note 2).
- 4.2.3 Close the valve sharply, remove the apparatus and determine the mass of the apparatus and the remaining sand ( $m_2$ ).
- 4.2.4 The mass of the sand required to fill the cone and base plate is calculated by the difference between the initial mass (4.1.3), and the final mass (4.2.3). Record this mass as the cone correction ( $C_c = m_1 - m_2$ ) (Note 3).

*Note 3 – For each container/bag of sand there will be a unique cone correction and sand calibration factor. Each sand-cone and matched base plate will also have a set of unique cone corrections and bulk sand densities. If more than one sand-cone apparatus is available, the sand-cone and base plate should be marked and the associated correction/density factors recorded.*

- 4.3 Determining the bulk density of sand ( $D_B$ ) to be used in the field test.
- 4.3.1 Replace the sand removed in the funnel determination according to section 4.1, close the valve, and determine the mass of the apparatus and sand ( $m_3$ ).
- 4.3.2 Position the calibration container on a clean, level, plane surface. Place the base plate on the calibration container (Note 1). Invert the apparatus and seat the funnel in the recess of the base plate.
- 4.3.3 Open the valve and keep open until the sand stops flowing (Note 2).
- 4.3.4 Close the valve sharply, remove the apparatus and determine the remaining mass of the apparatus and sand ( $m_4$ ).
- 4.3.5 Calculate the mass of the sand needed to fill the container, funnel and base plate. Subtract the final mass (4.3.4) from the initial mass (4.3.1).

- 4.3.6** The mass of the sand needed to fill the container only is determined by subtracting the mass of the cone correction (4.2.4) from the total mass required to fill the container with the funnel and base plate (4.3.5).

**4 Cone Correction and Bulk Density Factors:** (continued)

- 4.3.7** Determine the bulk density of the calibration sand (sand calibration factor). Divide the mass of the sand needed to fill the container (4.3.6), by the volume of the calibration container as determined according to MT 203.

$$D_B = (m_3 - m_4 - C_c)/V_c$$

- 4.3.8** Record this factor for future reference (Note 3).

**5 Procedure:**

- 5.1** Determine the density of the soil in place as follows:

- 5.1.1** Fill the apparatus with sand according to Section 4.1. Record the total mass ( $m_5$ ).

- 5.1.2** Prepare the surface of the location to be tested so that it is a level plane.

- 5.1.3** Seat the base plate on the prepared surface. Dig the test hole inside the opening of the base plate, being very careful to avoid disturbing the soil that will bound the hole. Soils that are essentially granular require extreme care. Place all loosened soil in a container, being careful to avoid losing any material. Care must be taken to avoid moisture loss during excavation.

- 5.1.4** Place the apparatus on the base plate, open the valve. After the sand has stopped flowing, close the valve (Note 2).

- 5.1.5** Weigh the apparatus with remaining sand ( $m_6$ ) and record..

- 5.1.6** Weigh the moist material that was removed from the test hole.

- 5.1.7** Mix the material thoroughly and secure and weigh a representative sample for moisture determination.

- 5.1.8** Dry and weigh the soil sample for moisture content determination in accordance with MT 227. Calculate the moisture content to the nearest 0.1percent.

- 5.1.9** The minimum test hole volumes suggested determining the in-place density of soil mixtures are given in Table 1. The table shows the suggested minimum mass of the moisture content sample in relation to the maximum particle size in soil mixtures.

**Table 1**  
**Minimum Test Hole volumes and Minimum Moisture Content Samples**  
**Based on Maximum Particle Size**

Maximum Particle Size		Minimum Test Hole Volume		Minimum Moisture Content Sample, g.
mm	Alternate	cm <sup>3</sup>	cu ft	
4.75	No. 4 sieve	710	0.025	100
12.5	½ in.	1415	0.050	250

25.0	1 in.	2125	0.075	500
50.0	2 in.	2830	0.100	1000

## 6 Calculations:

### 6.1 Calculate the volume of the test hole ( $V_H$ ):

$$V_H = (m_5 - m_6 - C_c)/D_B$$

Where:

$V_H$  = volume of test hole,

$m_5$  = initial mass of apparatus and sand,

$m_6$  = final mass of the apparatus and sand,

$C_c$  = Cone Correction, and

$D_B$  = bulk density of the sand.

#### 6.1.1 Calculate the volume of the test hole to the nearest 1 cm<sup>3</sup> (0.0001 ft<sup>3</sup>).

### 6.2 Calculate the dry mass of the material removed from the test hole as follows:

$$M_{DS} = (M_{WS}/(1 + (w/100)))$$

where:

$M_{DS}$  = dry mass of the material removed from the hole,

$M_{WS}$  = moist mass of the material removed from the test hole, and

$w$  = percentage of moisture, in the material removed from the test hole.

#### 6.2.1 Calculate the dry mass of the material to the nearest 1 g (0.01 lb).

### 6.3 Calculate the in-place dry density for the material removed from the test hole as follows:

$$D_D = M_{DS}/V_H$$

where:

$D_D$  = in-place dry density of the material removed from the hole,

$M_{DS}$  = dry mass of the material removed from the test hole (Section 5.2), and

$V_H$  = volume of the test hole (Section 5.1).

#### 6.3.1 Calculate the in-place dry density to the nearest 1 Kg/m<sup>3</sup> (0.1 lb/ft<sup>3</sup>).

*Note 4 – 0.001 g/cm<sup>3</sup> = 1 Kg/M<sup>3</sup>*

*Note 5 – It may be desired to express the in-place density as a percentage of some other density, for example, the laboratory maximum density determined in accordance with MT-210. This relationship can be determined by dividing the in-place density by the maximum density and multiplying by 100.*